Heuristics as cognitive tools for pursuing sustainability

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10 Heuristics as cognitive tools for pursuing sustainability

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1 Introduction

The mission of this volume includes a seeming paradox. On the one hand, the book discusses ad hoc ways of framing and dealing with wicked sustainability challenges; on the other, it aims to develop a new approach to tackle such challenges. Can there be a systematic approach for ad hoc ways of doing things?

We think so. From the epistemological point of view, we are facing a potential God trap. Any novel way of explaining the world within a higher-level explanatory framework than the existing ones can itself be criticized as just another explanation within yet another higher-level explanatory framework, resulting in endless explanations without closure. Yet we believe we are not in such a trap. The ecological pragmatism that characterizes the chapters of this volume stresses the importance of crafting tools of observation for very different environmental contexts. Despite the variation in contexts, we think there is something systematic about the toolbox.

We suggest that this systematic can be understood from the perspective of autopoietic epistemology (Fuchs 2001; Luhmann 1995; Maturana and Varela 1980), which provides a scheme to describe the toolbox of observation in different environmental contexts. In this view, the heuristics discussed in the chapters can be seen as instruments with which cognitive actors adapt to and survive in particular environments (cf. Gigerenzer 2008; Todd et al. 2012). Conceptualizing the ad hoc tools of researchers as heuristics is thus not only a move away from the rationalist programme of classical epistemology, which focuses on the epistemic goal of having justified beliefs, but also an attempt towards a more embodied understanding of knowledge.

In this chapter we explore the cognitive foundations of the heuristic approach that unites the volume. We discuss the key challenges taken up in this book, sustainability and transdisciplinarity, in the light of embodied, autopoietic epistemology. The question we address is whether better understanding of autopoiesis and embodied cognition could provide a basis for designing transdisciplinary heuristics for dealing with complex sustainability problems. We will show that an embodied approach to solving sustainability problems does not refer to a higher-level explanatory framework, but to a search for solutions within and between the autopoietics of complex systems.

From this perspective, we argue, heuristics may open up a new direction in transdisciplinary sustainability studies. The rationale is twofold. First, heuristics and their building blocks resonate with the capacities prepared by the genes of a species. Unlike 'disciplinary' tools of observation, some simple heuristics are likely to make sense across social and environmental contexts, as individuals share the same biological and ecological inheritance (Todd et al. 2012). Second, the explicit notion of knowledge as an instrument of adaptation and survival, rather than a transcendent good, puts transdisciplinarity at the centre of our knowledge enterprise. Human knowledge is not simply *about* the world, but influences and is influenced by the world (Cilliers 2010; Ison 2010). In this sense, transdisciplinary research can itself be understood as a co-creative heuristic that, when successful, can influence the autopoiesis of disciplinary systems.

The chapter is structured as follows. First, we take a closer look at the dilemmas of observation, raised in Chapter 1, from the perspective of autopoietic epistemology. We then discuss heuristics as cognitive devices with which autopoietic observers make sense of the sustainability challenges they face in particular environments. As an exploration of this approach, we analyze simple heuristics of sustainability from the perspective of cognitive linguistics and embodied cognition (Clark 2011; Feldman 2006; Lakoff and Johnson 1999; Shapiro 2011; Thelen 2000), and illustrate our arguments with frequent reference to the cases presented in earlier chapters. We then return to the more general epistemological challenge of transdisciplinarity, and sketch out elements of a transdisciplinary heuristic as a form of observing.

2 Observer's dilemma and the theory of autopoiesis

While psychologically oriented cognitive science has explained how we process, share and integrate information, both social scientific and biological approaches to cognition have addressed information in the context of complex systems. Since the world itself contains no information, only unstructured complexity, information is information *for* an observer in this world. What things are, they are for an empirical observer, and an observation is what it becomes *in relation to other observations.* An observer is anything equipped to apply distinctions to its environment or, more precisely, that part of the world which is an observer's niche. Some observers are results of natural evolution, and positioned in a biophysical environment – such as a body, its immune system, or brain; or an entire species, such as bacterium or human species. Other observers are results of social forces or relations, and positioned in a human culture – such as groups, organizations, nation states, social movements and sciences.

This concept implies that the ability to 'know' is attributed to the autopoietic character of observers, rather than some distinctly human property, such as consciousness or intersubjective agreement. A defining characteristic of the organization of autopoietic systems is their ability to observe their surroundings, that is, their ability to develop an epistemological relation with their environment. This unavoidably involves a selective construction of reality, which only makes sense in relation to the autopoiesis of specific entities (Kunneman 2010).

Human beings make distinctions about the world according to their biological cognitive structure, the cultural networks they are part of, and their positions in those networks. In this view, individuals are not self-contained observers, but nodes in multiple networks of observing. Our biological and evolutionary inheritance as human beings constitutes such a network – that of human species – but it is only one of the networks that observe 'through' us. As social and cultural beings, we observe the world around us in the light of our cultural inheritance, language most importantly but also other systems of interpretation, which are self-referential modes of observing.

From the perspective of autopoietic epistemology, knowledge looks very different from what it is when viewed from the perspective of classical epistemology. However, such a view is not incompatible with modern cognitive science. In their challenge to prevailing models of Western thought, George Lakoff and Mark Johnson (1999) argue that human reason is: (1) embodied; (2) evolutionary; (3) universal only in that it is a capacity all humans share; (4) mostly unconscious; (5) largely metaphorical and imaginative; (6) and emotionally engaged. Their position reflects a tradition of understanding that is not commonly appreciated in science but which is increasingly informed by the last 40 years of cognitive science research (McClintock et al. 2003).

What are the implications of this view to scientific knowledge? According to social theorist Stephan Fuchs (2001, 2002), disciplines produce knowledge in the sense that they create and maintain coherence against entropy and dissolution. Coherence is the outcome of connectivity and ties within a network, and then of higher internal than external connectivity and density. As such networks 'learn', their results become increasingly dissimilar to the original inputs, including the world at large, but more similar to themselves. The epistemological implication is that learning, or accumulation of knowledge, is not an increasing proximity to the real world, but an increasing self-similarity. Because of this self-similarity, a network, such as a discipline, is always 'simpler' or more coherent than the world at large.

In observing the world, disciplines develop distinctive patterns of perception and technologies of knowing. These become institutionalized as the default modes of operation that provide some unity and continuity to the ever-changing themes and referents of these operations themselves. But, as Lyytimäki and Petersen (Chapter 3), Banister (Chapter 4) and Paloniemi and Vainio (Chapter 9) in this volume show, they also produce patterns of blindness, because 'a way of seeing something is always, at the same time, a way of not seeing something else' (Burke 1984 [1933]: 49). The institutional modes of observing, which become the black boxes of a discipline, are themselves a condition for learning, especially for cumulative advances, since learning cannot occur if everything changes at the same time – then there is not progress but breakdown (Fuchs 2001: 287).

The cumulative advances of knowledge, however, have little relevance as such beyond the confines of the discipline's niche. Outside of its niche, an observation does not 'disclose' the world, but adds itself to the world. The world is now more, not less, complex than before. Hence the complexity or wickedness of 'real world problems', such as sustainability. As Frodeman maintains (Chapter 11, this volume), more disciplinary knowledge production will not resolve problems such as climate change, but reveal ever more areas of ignorance and thus of further research.

It is in this context that the transdisciplinary challenge of sustainability seems most urgent. What is the status of knowledge, and how can it help us on our way towards sustainability? The embeddedness of knowledge in its context of production is often understood as causing biases and distortions and thereby undermining the epistemic status of scientific knowledge. An alternative conclusion, however, would be that knowledge is a real accomplishment of the structural coupling between an observer and its niche, and has thus an embodied rather than transcendental meaning. While not necessarily antithetical to the usual constructivist view, this conception would trigger very different connotations by linking constructivism with the realism of the embodied process of cognition, which is a product of nature and nurture (e.g. Maturana and Varela 1992; Proulx 2008). This suggests we should search solutions to sustainability problems by making explicit use of the autopoietic dimension of knowledge.

3 Heuristics for sustainability from an autopoietic perspective

Autopoietic systems have an interest in surviving and reproducing or expanding, and undergo structural changes as adaptive responses to their environment. The concept of autopoiesis was originally developed by two cognitive biologists, Humberto Maturana and Francisco Varela (e.g.1980), but the social theorist Niklas Luhmann (e.g. 1995, 1996) has argued that the idea applies not only to biological but also to a large number of non-biological systems. Since we are concerned about our survival as a species, the systems of interest here are coupled human–environment systems, also known as social–ecological systems. The cognitive heuristics of a human being can be understood as adaptive responses to natural environments, both ecological and social (Gigerenzer 2008).

Let us re-iterate the situation of concern as it was identified in Chapter 1. In sustainability challenges, such as the diverse cases described in the preceding chapters, we typically have a *group of people* who are concerned about the sustainability of a particular environmental entity, which in contemporary environmental studies is increasingly characterized as a *social–ecological system.* The system can be defined in various ways. According to Elinor Ostrom (2009), for example, the system is composed of a resource system (e.g. a forest), resource units (trees), resource users (foresters) and a governance system (forestry institutions and organizations). The group applies some cognitive strategy, a *heuristic*, to identify and tackle the challenges. In line with the axiom of Simon's scissors, success in facing the challenges depends on how well the heuristic that the group applies matches the situation in the social–ecological system. As we shall see, however, from the autopoietic perspective this matching does not refer to links between separate entities, but rather an embodied coupling of the group (the observer) and the social–ecological system (the observed). We call this coupling a heuristic (the act of observation).

The group resolving sustainability challenges may range from a local community tackling its resource management issues to a group of experts developing analytical solutions to global environmental problems (Ostrom 2005). Since heuristics are reasoning devices, the group can be thought of as an epistemic community, that is, 'a specific community of experts sharing a belief in a common set of cause-and-effect relationships as well as common values to which policies governing these relationships will be applied' (Haas 1989: 384). The community may evolve during the search for a solution to the environmental problem, involving possibly only so-called 'stakeholders' at an early stage but incorporating 'analysts' at a later stage. But the way the members of the community formulate their beliefs and values about the social–ecological system is constituted by – in fact, embodied in – the social–ecological system itself.

The epistemic community and its environment are not separate subsystems but rather function as an autopoietic entity – a social–ecological network. It is a network of relational processes that produce components which continuously regenerate and constitute the network in a particular domain, or what we called 'niche' in Section 2 (Maturana and Varela 1980: 78–79). The critical difference with classical epistemology is that the components of the social–ecological system observed are also constitutive elements of the cognitive act of observation. In the language of Maturana and Varela (1980: 109), a proper observation of an autopoietic system as a unity requires that the distinction of system limits takes place in the domain of the components of the system. This account of observation is qualitatively different from the prescription found in many existing models of social–ecological systems, according to which stakeholder knowledge needs to be 'incorporated' in the models (see e.g. Ostrom 2007: Table 1; Walker et al. 2002: 8). Such approaches involve a translation of 'stakeholder' knowledge into the language of a model of human–environment interaction developed by 'analysts'. The autopoietic notion of observation requires instead that analysts and stakeholders understand social–ecological interaction as equally valid observers in the same niche of observation, with no translations of knowledge in between; and that the niche of observation is also the niche of the social–ecological system in question.

Recent advances in cognitive linguistics and embodied cognition theory provide guidance for specifying the components of a heuristic for sustainability such that those components are also components of the social–ecological system that the epistemic community strives to understand. According to embodied cognition researchers, 'cognition depends on the kinds of experiences that come from having a body with particular perceptual and motor capabilities that are inseparably linked and that together form the matrix within which reasoning, memory, emotion, language, and all other aspects of mental life are embedded' (Thelen 2000: 4). Concepts are therefore embodied as well: 'An embodied concept is a neural structure that is actually part of, or makes use of, the sensorimotor system of our brains' (Lakoff and Johnson 1999: 20).

The fundamental embodied concept that connects subjective experience with sensorimotor experience is known as the *primary metaphor*. It is formed as a mapping from the source domain of sensorimotor activity to the target domain of subjective experience (Lakoff and Johnson 1980, 1999; Gentner 1983; Gentner et al. 2001). As Jerome Feldman explains (2006: 202), 'when subjective and sensorimotor experiences are brought together in an episode, both domains are coactive. This, according to association learning theory, causes the strengthening of connections between the neural circuits supporting the different modalities. The new, strengthened connections physically constitute the metaphorical mapping.' For example, in the primary metaphor *affection is warmth*, the source domain's sensorimotor experience of temperature is projected onto the target domain's subjective experience of affection (Lakoff and Johnson 1999: 50–54). It is easy to see how embodied experiences of the human animal evolution, such as being held in the arms of one's mother, would generate associative mappings such as this (Hukkinen 2012).

We suggest that the primary metaphor is a good candidate for a constitutive component of an epistemic community's heuristic for sustainability, because it is in the niche of the observer, the observed and the act observation. It is in the niche of the observing human being in the sense that the firing of neurons takes place in the human mind. It is in the niche of the observed social–ecological system in the sense that the generic physical characteristics of any social–ecological system – such as force, gravitation, enclosure, location, path, physical artifact, colour, warmth, texture and smell – trigger the mind's sensorimotor experiences. And primary metaphor is in the niche of observation because observation is an episode of the mind interacting with the social–ecological system during which the subjective and sensorimotor experiences are automatically co-activated at the neuronal level. Any heuristic for making sense of a social–ecological system that is built from primary metaphors is therefore structurally coupled with the system, because the sensorimotor activity triggered by human interaction in the system is automatically mapped at the neuronal level onto the universally shared abstractions expressed in the primary metaphors. Observation of the social–ecological system and the heuristic model triggered by it can thus only take place in the niche of the components of the system – a signature of autopoiesis.

The implications of autopoietic epistemology are profound in comparison with classical epistemology. Studying a social–ecological system necessitates being part of that system, not outside of it. Any effort to take analytical distance from the system, which classical epistemology posits as a prerequisite of objective observation, signals to the autopoietic analyst a structural inability to observe. Any effort to distance oneself from emotional attachment to the things under observation signals to the autopoietic analyst a neglect of the reality of observation, namely, that all observation automatically triggers emotions. And a vision of perfecting a conceptual system that abstracts from the sensorimotor reality of the social–ecological system is incomprehensible to the autopoietic analyst, who aims to uncover the sensorimotor experiences that a particular abstraction mobilizes. These contrasts point toward a need to specify the tools of autopoietic observation, or the heuristics for sustainability.

4 Cognitive tools for pursuing sustainability

As Peter M. Todd, Gerd Gigerenzer and their colleagues (2012) note, cognitive heuristics have virtually never been treated as normative, only as descriptive models. A cognitive science perspective suggests that 'people take their heuristics off-the-shelf, use them unknowingly and automatically, and rarely worry about their accuracy. An inherent part of human nature, these broader, less discriminating sorts of heuristic generally trump strategic decision making' (Kuklinski and Quirk 2000; see also Paloniemi and Vainio, Chapter 9, this volume). In political behaviour, for example, people often lack the contextual knowledge needed to use heuristics intelligently, or in fact to use them at all (Delli Carpini and Keeter 1996). Therefore, in the ordinary parlance, as well as in rationalist discourses of decision making and problem solving, heuristics is usually linked with 'biases', 'shortcuts' and other mainly flawed procedures.

However, given recent developments in the normative study of cognitive heuristics (Todd et al. 2012), combined with the increasing chasm between the rationalist programme of classical epistemology and the complexity of human knowing, we believe that heuristics could play a key role in tackling sustainability problems. While many attempts to advance sustainability, not least those that advocate transdisciplinarity, end up with conflicting views, complicated procedures and institutional inertia, cognitive heuristics may provide welcome 'shortcuts' towards more sustainable paths of action. In this section, we apply the above concepts from cognitive linguistic and embodied cognition to show how heuristics for sustainability can be defined, identified and refined with a view to influence the behaviour of autopoietic actors.

4.1 Fit between heuristics and sustainability challenges

Not all heuristics are equally helpful in guiding behaviour towards greater sustainability. As we have seen in the previous chapters, some heuristics simply work to maintain the status quo (Paloniemi and Vainio, Chapter 9) or prevent us from seeing alternative paths of action (Lyytimäki and Petersen, Chapter 3; Banister, Chapter 4). One way to evaluate heuristics for sustainability is to assess the goodness of fit between the heuristic and the sustainability issues it aims to tackle. In the light of autopoietic theory, this assessment has two aspects. As an instrument of adaptation, a heuristic for sustainability is both an explanation of a social–ecological system as an emergent structure capable of renewing itself, and a cognitive attractor of individuals whose recruitment reinforces the integrity of the system (Hukkinen 2012; Antal and Hukkinen 2010). We therefore distinguish two measures of fit, empirical and cognitive.

'Empirical fit' is the test usually applied to scientific theories, measuring the extent to which the theory's description of a sustainability phenomenon matches the observed reality of the phenomenon. In contrast, 'cognitive fit' measures the extent to which the theory's description of sustainability matches the cognitive reality of observers, such as human beings. Cognitive fit is determined not by the properties of a particular theory but by the way in which it resonates with the autopoietic dynamics of an observer. Cognitive fit has two aspects, *cognitive appeal* and *cognitive optimality* (Hukkinen 2012). A structure of meaning, such as a scientific theory, or in our case, a heuristic for sustainability, has cognitive appeal when it contains primary metaphors associated with positive subjective experiences, such as happiness, affection and goodness (Hukkinen 2012; Lakoff and Johnson 1999). A heuristic for sustainability can also be evaluated in terms of its cognitive optimality, which measures the ease with which the human mind can imagine and simulate the heuristic (Fauconnier and Turner 1998; Hukkinen 2012). When a heuristic is cognitively optimal, the human mind can 'run' it effortlessly in imaginative mental simulation, without violating the integrity of the heuristic and its component relations (Fauconnier and Turner 1998).

We focus in the following on the significance of cognitive fit for the development of transdisciplinary sustainability heuristics, and illustrate our arguments with reference to the cases presented in earlier chapters. We divide the design of transdisciplinary heuristics for sustainability into two stages: identification and refinement of heuristics. Identification of heuristics refers to various cognitive tools with which knowledge originating in radically different traditions and practices can be integrated so that it becomes useful for tackling sustainability challenges. Refinement of heuristics refers to ways of improving the cognitive appeal and optimality of the sustainability heuristics identified in the first stage.

4.2 Identifying sustainability heuristics

Identification of sustainability heuristics draws on cognitive tools of knowledge integration, which include the various methodologies of analogical alignment. These range from the identification of simple metaphors to complex blends of metaphors. Many cognitive scientists argue that the human mind encounters and understands new things by constructing analogies (Lakoff and Johnson 1999; 1980; Gentner et al. 2001; Fauconnier and Turner 2002).

The principle of constructing analogies is simple. We disaggregate an unfamiliar phenomenon (also known as the target space) into relations between elements. In trying to understand the target space, we look for similarities between its relations and those of phenomena more familiar to us. Having found among the familiar phenomena one (also known as the base space) with relations that best match those of the target space, we map the relations of the base space onto the target space (cross-space mapping). We say that the target space is 'like' the base space.

But analogies are also themselves elements of more complex mental structures called conceptual blends. The blend does not simply add the two partial spaces of knowledge. Instead, blending completes what are only barely distinguishable patterns in the two partial spaces of knowledge, which results in a new space of knowledge qualitatively different from the partial inputs (Fauconnier and Turner 2002; Hukkinen 2008).

The ability to construct conceptual blends is a prerequisite of the search for transdisciplinary solutions to sustainability problems. An autopoietic view of knowledge is not, as such, very promising for transdisciplinary collaboration, with its imagery of self-sufficient systems aiming at their own reproduction, maintenance and survival (Maturana and Varela 1980). Yet the notion of observation as an ability of the observer to make distinctions in the niche of the observed indicates an interactive potential. From the autopoietic perspective, blending is a process of cognitive entrainment in which two or more separate epistemic communities successfully synchronize their respective heuristics for sustainability. As a result, formerly separate communities may begin to merge into one if they discover that they operate and make observations in the same social–ecological niche. The emergence of epistemic communities and collective construction of blends can even be facilitated with deliberative procedures (Hukkinen 2008; Levänen and Hukkinen 2013).

The preceding chapters contain abundant evidence of the applicability of both simple and complex analogical alignments in transdisciplinary heuristics. Their value is evident especially in transdisciplinary problem *framing*, which is the overall theme covered in Chapters 2 through 5 in Part I of this volume. An example of a straightforward analogy is Banister's

(Chapter 4) use of Barbara Adam's timescape approach, which draws an analogy between space and time to arrive at the analytical concept of timescape, in an analogy with the spatial concept of landscape. Huutoniemi and Willamo (Chapter 2) develop a systematic approach for identifying more complex analogical alignments useful for solving sustainability problems. In what they call outward oriented thinking, objects of observation are understood in relation to other objects located outside the description of the object of observation, either horizontally (when the alignment takes place across substantially different objects) or vertically (when the alignment takes place across objects located at different system levels).

Paloniemi and Vainio (Chapter 9) explore the use of cooperative heuristics in natural resource management, and show that dialogue between landowners and policy implementers is likely to facilitate biodiversity policy. Compared to another commonly used socio-cognitive heuristic, trust, dialogue seems to be an efficient strategy for the different stakeholders to pursue their respective goals in harmony.

4.3 Refining sustainability heuristics

Refinement of transdisciplinary sustainability heuristics aims to improve the cognitive appeal and optimality of the analogical alignments identified earlier. Recall that a heuristic for sustainability has cognitive appeal when it contains primary metaphors associated with positive subjective experiences, while cognitive optimality measures the ease with which the human mind can 'run' the mental constructs contained in a heuristic (Fauconnier and Turner 1998; Hukkinen 2012; Lakoff and Johnson 1999).

Assessment of cognitive appeal is by no means straightforward, because the subjective experiences with which a particular sensorimotor experience is associated in a primary metaphor cannot be categorized as unambiguously positive or negative. Some primary metaphors connect particular sensorimotor experiences with reasonably unambiguous positive or negative experiences, such as *affection is warmth*, *happy is up*, and *bad is stinky*. Others are normatively more ambiguous, such as *important is big*, *intimacy is closeness* and *more is up*. Finally, there are primary metaphors whose normative connotations are difficult to identify. Instead, these metaphors link logical or physical abstractions with sensorimotor experiences, for example, in *categories are containers*, *similarity is closeness* and *time is motion* (Table 10.1).

We suggest that the variation in the emotional content of primary metaphors offers a powerful tool for refining sustainability heuristics, because it forces sustainability analysts to face head-on the inherently subjective and emotional content of even the most objective scientific messages. At one extreme, should the analysts resort to primary metaphors with unambiguous links to emotional subjective experiences to convey their message, they commit themselves to triggering strong positive or negative emotional reactions in the target audience. At the other extreme, should they use heuristics

Table 10.1 Primary metaphors.

Subjective experience	*Sensorimotor experience*
Affection is	Warmth
Important is	Big
Happy is	Up
Intimacy is	Closeness
Bad is	Stinky
Difficulties are	Burdens
More is	Up
Categories are	Containers
Similarity is	Closeness
Linear scales are	Paths
Organization is	Physical structure
Help is	Support
Time is	Motion
States are	Locations
Change is	Motion
Actions are	Self-propelled motions
Purposes are	Destinations
Purposes are	Desired objects
Causes are	Physical forces
Relationships are	Enclosures
Control is	Up
Knowing is	Seeing
Understanding is	Grasping
Seeing is	Touching

Source: Compiled from Lakoff and Johnson (1999); Feldman (2006).

composed of primary metaphors with links to physical or logical abstractions, they choose to tone down the emotional reactions of the audience.

The preceding chapters provide evidence of the significance of cognitive appeal in refining sustainability heuristics. Lyytimäki and Petersen (Chapter 3) reveal the social blind spots of resorting to the cognitively appealing but normatively ambiguous metaphor of ‘ecosystem services’. As ‘service’ and ‘support’ are closely related (Roget’s International Thesaurus 1977; Merriam-Webster Thesaurus 2013), ecosystem services evoke the primary metaphor *help is support* (Table 10.1). However, as the authors point out, it is important to ask who is being helped and what is considered help. Since a primary metaphor is evoked, there is a danger that individuals unconsciously and without reflection accept ecosystem services as an unambiguous social good. Lyytimäki and Petersen reveal this danger by highlighting the diversity of human uses, perceptions and valuations pertaining to the notion of ‘service’.

Banister (Chapter 4) reframes the influential metaphor of ‘travel time’ by widening the spectrum of primary metaphors it mobilizes. The predominant paradigm of transport policy understands ‘travel time’ as implying the primary metaphors *time is motion* and *difficulties are burdens* (Table 10.1).

Since *time is motion*, more time consumed for the same amount of movement is a difficulty, as Banister illustrates. And since *difficulties are burdens*, it is necessary for transport policy to minimize the travel time spent. Banister proposes an alternative, which effectively mobilizes the primary metaphors *organization is physical structure*, *help is support*, *categories are containers* and *purposes are destinations*. Banister argues that the purpose of transport policy ought to be the social allocation of travel through physical transport infrastructure. In other words, he is effectively arguing that social *organization is physical* transport infra*structure*. According to Banister, this social organization can prevent the inequalities and waste resulting from the minimization of travel time. In other words, the novel social allocation and the physical infrastructure *help to support* the social good. Banister also recognizes that the objective of travel time minimization reflects only one among many social meanings attached to travel time (*categories are containers*), and that this variety ought to be reflected in the direction of future transport policies (*purposes are destinations*). Thus, Banister is able to strengthen his argument for novel transport policy by invoking powerful alternative primary metaphors.

Cognitive optimality shifts the focus of analysis from the primary metaphors to conceptual blends, that is, more complex metaphorical constructs composed of primary metaphors. Fauconnier and Turner (1998) argue that the ease with which the human mind can run a mental construct is measured by cognitive optimality. They propose five interrelated optimality principles for conceptual blends: integration, topology, web, unpacking and good reason. Here we take just two of them – topology and web – under closer inspection, because these two actually incorporate elements of the remaining three. A conceptual blend has topology when the relations of an element observed in the blend match those of its counterpart in an input space. The blend is an integrated web when manipulating the blend as a unit maintains its connections to the input spaces without surveillance or computation (Fauconnier and Turner 1998: 162–63). To illustrate the workings of topology and web, let us take a closer look at Huutoniemi and Willamo's contribution to this book in Chapter 2.

Huutoniemi and Willamo develop a heuristic model of sustainability issues that they call the 'architecture of an environmental problem' (here we refer to it as AEP). It is a conceptual blend between the 'ecological system' and the 'human system', as the authors treat environmental problems 'as emergent and systemic features of human–environment interaction'. They stress that this distinction does not imply an ontological dualism between humanity and nature. However, it is epistemologically helpful, because what defines an environmental problem is its association with ecological exchange between human systems and ecological systems. In their ontological view, human society is a social construction emerging from natural evolution. As a result of these emergent properties, the rationales of human systems differ from those of the natural systems. It therefore makes heuristic sense to depict the AEP (or what other researchers in the field have called the social–ecological system) as a causal arrow diagram made of the human system with its internal causal interactions and the ecological system with its internal causal interactions, and then link these two systems with a 'discharge/intake' box and numerous causal feedbacks (Chapter 2, Figure 2.2).

The AEP is a cognitively optimal conceptual blend. It displays topology, because the relations of the elements observed in the blend match those of its counterparts in the inputs. The elements and relations presented in the figure belong either to the human system or the ecological system. Obviously, what is included in the AEP is only a partial depiction of all the elements and relations of the human system and the ecological system, respectively, as only those elements and relations pertinent to human–environment interactions have been incorporated. The AEP also contains the hallmark of blend topology, namely, an element identifiable in both inputs: the 'discharge/intake' element, which is a neutral event for the human system, but becomes consequential in the ecological system, comparable in its significance to 'ecological factors' that can cause an environmental 'change' and 'impact' (Chapter 2, Figure 2.2). The AEP is also an integrated web, because manipulating it as a unit maintains its connections to the inputs without surveillance or computation. Cause-and-effect relations pertaining to intentional human action form a seamless web with ecological causes and effects. Greenhouse gas emissions from industrial activities in the human system, for example, can easily be understood as feeding into the ecological system, only to cause ecosystem changes that feed back into the human system in the form of intensified storms, floods and droughts. The AEP can be mentally simulated with ease, despite the fundamental differences in the underlying rationales of the two component systems.

In Chapters 6 through 9 (Part II of this volume), which focus on transdisciplinary problem *solving*, cognitive optimality manifests itself in more complex manners. It cannot be determined at the level of an individual human mind, but in interaction between individuals who aim at a collective goal. The heuristics identified by Pohl (Chapter 6) as well as Hall and O'Rourke (Chapter 7) work precisely because they help individuals to move beyond the autopoietic maintenance of individual identities towards co-creative collective self-identification which enhances their prospects for reaching the goal. The variant of the Delphi method discussed by Varho and Huutoniemi (Chapter 8) is likewise a technique for refining the heuristics of individuals through an iterative process of deliberation and social learning.

5 Epistemology of transdisciplinarity reconsidered

We have come a full circle in the effort to sketch an outline of cognitive heuristics for sustainability. Recognizing the unproblematized status of the observers within the disciplinary approaches to wicked sustainability problems, we went on to develop an autopoietic account of observation. From the autopoietic point of view, universally objective observation is impossible because in a biological sense the act of observation requires that the observer is in the same niche, that is, in the same frame of reference, as the object being observed.

The biological fact of autopoiesis does not, however, question the usefulness of disciplinary approaches that rest on the assumption of universal observation. It only repositions them. In some circumstances – as Huutoniemi and Willamo, for example, illustrate in Chapter 2 – biologically false assumptions about dichotomies such as the observer and the observed, or humanity and nature, make perfectly reasonable sense. Disciplinary approaches are sometimes useful heuristics that emerge in the human mind in the course of human adaptation to specific social–ecological circumstances. This resonates with Daniel Dennett's hypothesis that although the 'Cartesian theatre' view of the mind can be shown to be cognitively and biologically false, its persistence in our thinking reflects its evolutionary usefulness for the survival of the human species (Dennett 1991). Where does this going around in a circle leave transdisciplinary inquiry of sustainability in the epistemological sense?

The notion of disciplines as autopoietic observers implies that the relationship between observations made by different disciplines is not logical or conceptual, but empirical and historical. Disciplinary networks can interact and communicate, even learn from each other, when there are actual relations and bridges between them. This can initiate interdisciplinarity. However, often interdisciplinarity turns into yet another specialty of its own, administered by special centers, organizations and institutes (Fuchs 2001: 265–87). We thus need to find a way out of the epistemological trap of narrow self-referentiality.

An epistemologically viable basis for transdisciplinary inquiry might be attained by systematically accounting for the observer in each act of knowledge, that is, the origin of knowledge in a particular cognitive system. As Edgar Morin (2008: 86) says: 'We believe we see what is real; but we see in reality only what this paradigm allows us to see, and we obscure what it requires us not to see.' This is indeed the crux of epistemological complexity. However, Morin's call for 'a paradigm shift, one tending in the direction of complexity' seems to include a paradox. While it is true that we cannot escape having a point of view, it is precisely in relation to a viewpoint that any meaning is possible at all. We cannot deal with complexity *in* its complexity, but we have to reduce that complexity when we try to understand it. This means that some aspects of the system are always left out of consideration. However, that which is left out interacts with the rest of the system in a non-linear way and we thus cannot predict what the effects of our reduction will be (Cilliers 2010).

As there is no objective way to do this reduction, there are always choices. This implies that dealing with epistemological complexity involves 'ethics of complexity'. The limits of disciplinary science do not so much pertain to simplistic, reductive, or disjunctive thinking as such, though modern science suffers from all these, but more to its lack of responsibility for the epistemological choices it makes. We see this as both an epistemological and ethical rationale for transdisciplinarity. It is only by making our epistemological stakes and institutional blind spots visible and open to adjustment that we can attain sustainability as a mutual goal between autopoietic observers. Transdisciplinarity implies that disciplines and other epistemic communities recognize each other as observers, and become more accountable for their epistemological positions.

This rationale, we argue, might take the methodological discussion of transdisciplinarity to a new level, which recognizes the earlier rationales of integration and accountability (see Huutoniemi, Chapter 1, this volume), but articulates them in an epistemologically more plausible manner. The methodological challenge of transdisciplinary research, as we see it, is to make sense of the world in the light of observations made by multiple different observers. In a messy situation, transdisciplinary researchers might adopt the role of a second-level observer, and from that position, approach the mess from a broader perspective. In the case of wicked sustainability issues, transdisciplinary research would not only deal with the problems as perceived by the stakeholders, but simultaneously explore the ways in which these stakeholders extract problems from the mess. Such a task requires adopting a constructivist and realist attitude at the same time in order to understand *how* they see, not only *what* they see.

Note, however, that the constructivist, second-order perspective is *not* a negation of the first-order perspective – they can be understood as a duality (Ison et al. 2007). The goal of transdisciplinary reflection is not to debunk the accounts of observers, but to estrange them so as to be able to reflect them from a broader perspective. In this sense, transdisciplinarity is closer to 'reflective epistemology of practice' (Schön 1983) or 'systems practice' (Ison 2010) than to sociology of knowledge, for example. Contrary to the latter, the results of constructivist observation are not fed into a second-level network of constructivists, to make a difference in that network, but back to the original puzzle at the first level. Constructivism is thus applied in an *ad hoc* manner to help make sense of the situation of multiple observers with different observations. It does not imply commitment to any *particular* constructivist epistemology, only that no observations exist unless they are constructed. Transdisciplinarity, we argue, should remain unattached to strict epistemological commitments, except the one that realizes the relational nature of knowledge.

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